

Analysis of Geometry Reasoning of Madrasah Ibtidaiyah Teacher Education Students Reviewed from Van Hiele's Geometry

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Abstract:

Students in college tend to be active in organizations. Student abilities in terms of academics are one of the benchmarks in the development of students' emotions in organizations. The topic of this article in terms of academic students is geometry ability which focuses on PGMI students at the STAI Nurul Huda Kapongan campus. To determine the existence of geometry levels, students are given a van Hiele geometry test sheet consisting of 25 multiple-choice questions. Leveling is done in stages. Students must pass the first 5 questions to get level 0, with students must be able to answer at least 3 questions correctly for the first 5 questions. The next 5 questions can be said to be passed if the previous 5 questions have been able to. Van Hiele geometry leveling consists of 5 levels. Level 0 is visualization, level 1 is analysis, level 2 is informal deduction, level 3 is deduction, level 4 is rigor. The researcher also compiled a geometric reasoning test sheet with 7 indicators. The formulation of the problem in this study is how the geometric reasoning ability of PGMI students at the STAI Nurul Huda Kapongan campus is reviewed from van Hiele's theory. A geometry ability test was administered to all 70 students. Students were grouped based on their geometry level. The results of the geometric reasoning test were analyzed and described based on the students' geometry level.

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INTRODUCTION

The ability to think critically and logically is a fundamental aspect of academic success, particularly in mathematics. Students who possess strong academic skills tend to have better thinking capabilities, which are essential in solving complex



problems and constructing sound arguments. Mathematical thinking involves several core principles, such as the ability to understand and solve problems, argue abstractly, build valid critiques, create mathematical models, use appropriate tools, and apply structured thinking (Arican & Özçakir, 2021; Yohannes & Chen, 2023). As emphasized by previous research, thinking is an essential skill that should be taught from an early age and serves as the foundation for all mathematical learning. This foundational thinking skill is pivotal not only for academic success but also for practical problem-solving in real-world scenarios.

A deeper understanding of the different types of mathematical thinking is essential. Mathematical reasoning is divided into two distinct types: creative reasoning and imitative reasoning (Woolcott et al., 2022). Creative reasoning involves novelty, flexibility, feasibility, and a strong mathematical foundation. In contrast, imitative reasoning can be further divided into memorized reasoning and algorithmic reasoning. Both types of reasoning play crucial roles in a student's ability to approach mathematical problems, yet creative reasoning is more aligned with higher-order thinking (Demir et al., 2023). The importance of these reasoning types is especially relevant when considering educational practices and curricula that aim to enhance mathematical thinking at various levels of learning.

Despite the recognized importance of mathematical thinking, social realities show that the ability to think critically in mathematics remains a challenge, especially in Indonesia. According to the Trends in International Mathematics and Science Study (TIMSS), Indonesia ranks low in mathematical thinking among global learners. This low ranking reflects significant gaps in students' ability to think critically and solve mathematical problems effectively. This issue points to the need for educators to focus on strengthening mathematical reasoning and thinking skills at all educational levels, from elementary to higher education (Fachrudin & Juniati, 2023). Geometric reasoning, in particular, plays a significant role in enhancing spatial and abstract thinking and is essential for students' success in mathematics.

Prior research highlights that the development of geometric reasoning among Indonesian students has been lacking. Middle and high school students, especially in Indonesia, often have limited experience with geometric thinking (Celik & Yilmaz, 2022). These students struggle to understand and reason about geometric concepts such as shapes, measurements, and transformations (Jablonski & Ludwig, 2023). The importance of focusing on geometric reasoning has become increasingly evident, as it underpins much of the higher-level mathematics that students will encounter in advanced academic and professional settings.

One of the major gaps in the current literature is the lack of research on geometric reasoning among university students. Most existing studies focus on younger students at the primary and secondary education levels, with limited exploration of how geometric reasoning develops and is applied at the university level. The research gap lies in understanding how university students integrate, generalize, and apply their prior knowledge of geometry to more complex and abstract mathematical problems. The novelty of this research lies in its focus on

university-level students' ability to reason geometrically, particularly using Van Hiele's Theory of Geometric Thought, which classifies geometric understanding into distinct levels that students progress through.

The purpose of this research is to analyze and assess the geometric reasoning abilities of university students, using Van Hiele's Theory of Geometric Thought. This study aims to identify how students at the university level understand and reason through geometric concepts, providing insight into their developmental stages. By investigating this, the research seeks to enhance educational strategies in mathematics, especially in the field of geometry, and provide recommendations for curriculum improvements. The focus will be on assessing students' progress through different levels of geometric thinking as outlined in the Van Hiele model.

This research is original in its focus on higher education students and their geometric reasoning abilities, using a well-established theoretical framework. Unlike previous studies that concentrate on younger students, this study brings attention to the importance of enhancing geometric reasoning at the university level, where students are expected to apply their understanding of geometry to more complex problems. By focusing on this critical area, the research aims to contribute new knowledge to the field of mathematical education, specifically regarding the teaching and learning of geometry in higher education. The findings will be beneficial for educators and institutions seeking to improve their teaching methods and curricula to better support students' development in mathematical reasoning

RESEARCH METHOD

This study employed a qualitative approach with a descriptive design. Descriptive research aims to collect data that provides an overview or explanation of a concept (Wood et al., 2020). This explanation can encompass conditions, events, or objects, including people or other elements, which are related to variables that can be described either numerically or verbally. The research was conducted at the STAI Nurul Huda Kapongan campus, selected for its unique characteristic of having not been previously used for studies concerning students' reasoning abilities.

The research procedure involved several steps: first, preparing the initial stages, including determining the research location, obtaining necessary permits, conducting on-site observations, interacting with potential respondents to identify research subjects, and preparing all necessary tools for the study. A Van Hiele geometry test was administered to all students, which had been validated by experts, including a doctorate in geometry, and consisted of 25 multiple-choice questions. The next step involved analyzing the test results to assess students' understanding based on the Van Hiele Theory, which includes five levels: level 0 (visualization), level 1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor).

The geometric reasoning ability test questions were first created and subsequently validated. Before administering the test, validation was carried out by distributing validation sheets to two mathematics lecturers. The data from the validation process were analyzed. If the questions were deemed valid, the process

continued to the testing stage. However, if the questions were not valid, revisions were made until the questions were validated by the reviewers. The geometric reasoning ability test was then administered to all PGMI students, covering the five levels of Van Hiele's theory: level 0 (visualization), level 1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor). Data reduction was performed, and two students were selected for each level of Van Hiele's theory using the snowball technique. Interviews were conducted with the students to supplement the results of the geometric reasoning ability test and to gather additional insights beyond the test results. The test results were then analyzed to determine the abilities or characteristics exhibited by each student in solving the geometric reasoning questions, and conclusions were drawn based on the analysis.

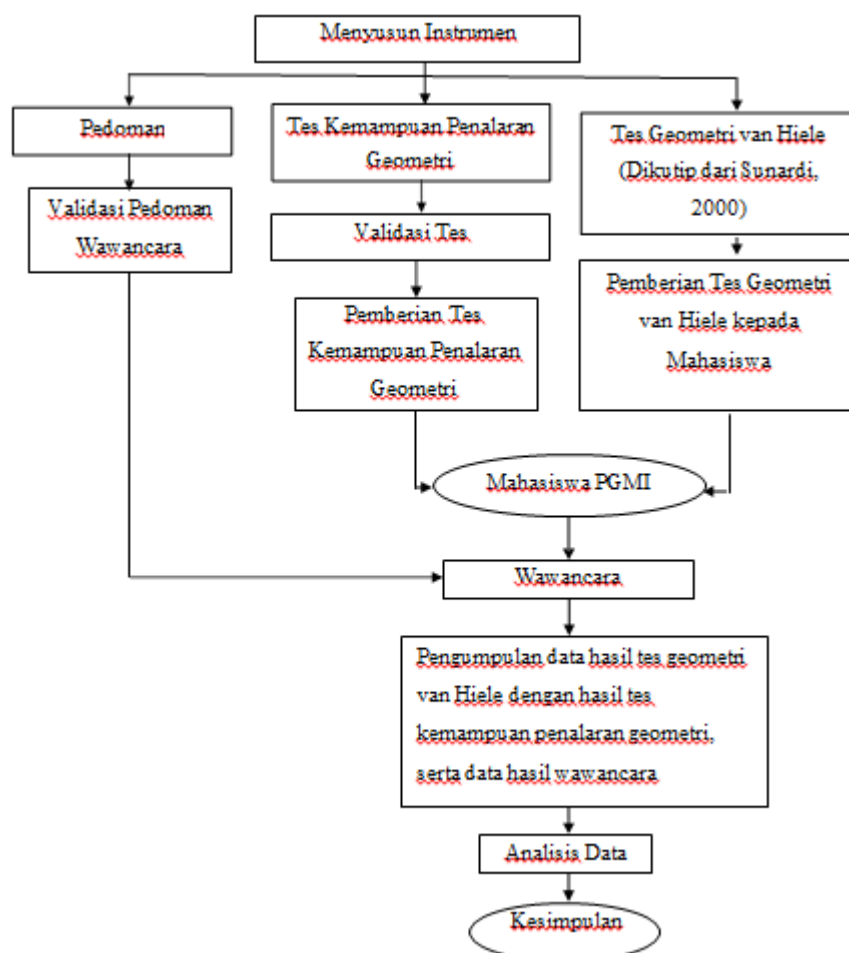


Figure 1. Research Scheme

Keterangan:

- : Jenis Kegiatan
- : Hasil Kegiatan
- : Hasil Analisis
- : Alur Kegiatan

For data analysis, a descriptive analysis method was applied. The data collected in this descriptive study were categorized into two types: qualitative and quantitative. Qualitative data were presented as sentences grouped into specific categories to draw conclusions. On the other hand, quantitative data were represented by numerical scores. From the results of the geometry ability test administered to PGMI students, scores were obtained, which were then used to select respondents for further analysis.

This study utilized both content validity and construct validity. A test is considered to have content validity if it measures specific objectives relevant to the material being taught. Additionally, construct validity is achieved if the test questions adequately measure each aspect of thinking, aligned with the instructional objectives. In other words, the questions must appropriately assess the cognitive aspects that correspond to the instructional goals (Maxwell, 2020).

The geometry reasoning test, the Van Hiele geometry test, and the interview guide were all evaluated by the validator. The assessment results were compiled into validation data and organized into a validation table for the geometric reasoning test, the Van Hiele geometry test, and the interview guide. Based on these results, the total average score for all aspects (Va) was determined. The Va value was used to assess the validity level of the geometric reasoning test and the Van Hiele geometry test. The total Va value, or average, was then compared with predefined instrument validity levels.

RESULT AND DISCUSSION

Result

Categorization of Van Hiele Geometry Ability

The results of the Van Hiele geometry test were categorized into five levels, which are as follows: Level 0 (visualization), Level 1 (analysis), Level 2 (informal deduction), Level 3 (deduction), and Level 4 (rigor). The test consisted of 25 multiple-choice questions, which had been validated.

Questions 1 to 5 were used to assess abilities at Level 0 (visualization). Questions 6 to 10 were designed to measure the skills at Level 1 (analysis). Questions 11 to 15 evaluated the ability at Level 2 (informal deduction). Questions 16 to 20 were assigned to assess Level 3 (deduction), and questions 21 to 25 were used to determine Level 4 (rigor). A student was considered to be at a specific level if they were able to correctly answer at least 3 questions at that level, after which they could progress to the next level.

After completing the Van Hiele geometry test, the students were given a geometric reasoning test, which was developed by the researcher and had been verified. The geometric reasoning indicators are outlined in Chapter 2 and consist of seven specific indicators.

Following the completion of the geometric reasoning test, data reduction was performed by selecting two students from each Van Hiele level. Subsequently, interviews were conducted with these selected subjects.

The data analysis process involved several steps, starting with data reduction. The activities involved in data reduction included reviewing the results of the students' work and the information gathered during the research process. Additionally, the interview responses, which served as supporting data, were analyzed to collect further insights. The data obtained from the test results and the interviews were then simplified for easier interpretation.

The data presentation involved describing the students' geometric reasoning abilities based on the Van Hiele Theory, utilizing the analysis from both the test results and the interview outcomes.

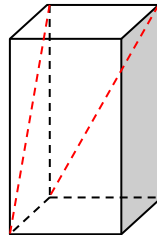


Figure 3. Picture on PGMI Student Geometry Question number 2

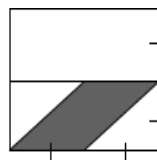


Figure 4. Picture on PGMI Student Geometry Question number 4

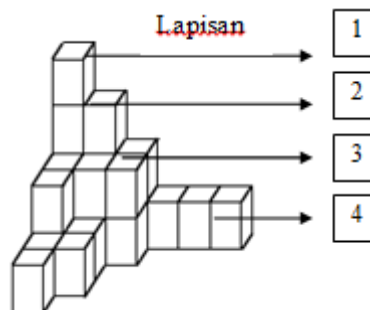


Figure 5. Image in PGMI Student Geometry Question number 7

Conclusions were drawn based on the analysis of the geometric reasoning test results and the subsequent interviews, in line with the interview guidelines. The conclusions were drawn for each subject, categorizing them into the appropriate Van Hiele geometric level: Level 0 (visualization), Level 1 (analysis), Level 2 (informal deduction), Level 3 (deduction), and Level 4 (rigor). The process of data analysis is depicted in the diagram below.

The subsequent section discusses the geometry problems provided to the students during the test. The students were given a series of geometry questions that had been validated by geometry experts, consisting of two doctoral-level faculty members specializing in geometry. Below are images of the questions

presented to the students during the test.

Figures 3, 4, and 5 show images from specific geometry questions provided in the PGMI student test, including questions 2, 4, and 7. These images were designed to assess various aspects of geometric reasoning, focusing on different levels of cognitive understanding as defined by Van Hiele's Theory.

After analyzing the students' responses, the results were compiled into the following table, which shows the percentage distribution of the students' performance across the five levels of the Van Hiele theory. The data indicates that none of the students reached Level 4 (rigor), which received a percentage of 0%. The distribution of students' performance across the other levels is as follows: Level 0 (visualization) achieved 27%, Level 1 (analysis) achieved 35%, Level 2 (informal deduction) achieved 22%, and Level 3 (deduction) achieved 17%.

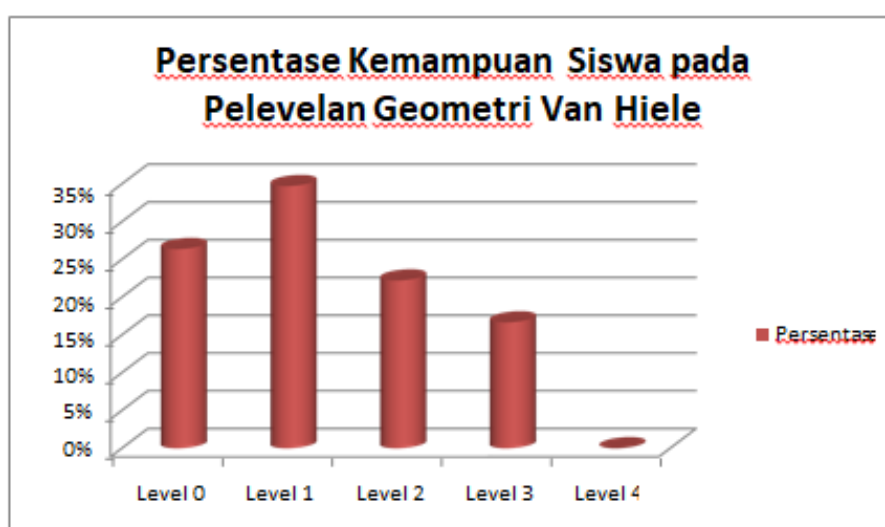


Figure 6. Results of the Percentage of Geometry Ability Score of PGMI Students

Informatio

1. Level 0 = $\frac{19}{72} = 26,38$

2. Level 1 = $\frac{25}{72}$

3. Level 2 = $\frac{16}{72}$

4. Level 3 = $\frac{1}{72} = 16,67$

5. Level 4 = $\frac{0}{72} = 0\%$

Figure 6 presents the results in the form of a diagram, illustrating the percentage of students' performance at each Van Hiele level. The diagram visually highlights that the majority of students (35%) were placed at Level 1 (analysis), indicating that a significant portion of the students had developed some analytical skills in geometry. However, the relatively low percentages at higher levels suggest that students still face challenges in advancing to more complex reasoning

processes, such as informal deduction and formal deduction.

These results suggest that while students show a decent understanding of basic geometric concepts (as indicated by the higher percentage in Level 1), there is still room for improvement in developing higher-order geometric reasoning skills. The absence of students reaching Level 4 (rigor) indicates that the majority of students are not yet able to perform highly abstract, formal, and logical reasoning required at the highest level of the Van Hiele theory.

This distribution of results emphasizes the need for targeted interventions in teaching and learning strategies, particularly those aimed at improving the ability to reason geometrically at higher levels. Further exploration into the factors contributing to these results, such as instructional methods, student engagement, and prior knowledge, could provide valuable insights for improving geometric reasoning skills in future cohorts.

DISCUSSION

The first finding of this study reveals that the majority of students performed at the lower levels of Van Hiele's theory, particularly at Levels 0 (visualization) and 1 (analysis). Many students at the secondary education level primarily rely on concrete reasoning and struggle to transition to abstract reasoning (Moustapha et al., 2022). Students often remain at these lower levels of understanding because they have not been sufficiently exposed to the cognitive processes required for higher-order thinking (Fütterer et al., 2022). Students at the high school level showed limited ability to engage in formal reasoning, particularly in geometry (Fardous, 2024). Both studies support the finding that students tend to remain at the visualization and analysis levels due to the lack of advanced instructional practices that encourage abstract reasoning and formal deduction.

Many students at the university level face challenges in progressing to higher levels of geometric reasoning, particularly Levels 3 (deduction) and 4 (rigor), due to insufficient exposure to abstract reasoning. Research has shown that students often remain at lower levels of understanding because their education does not adequately support the development of formal reasoning skills (Jauhari & Thelma, 2023). Studies also suggest that students at the higher education level struggle to engage in rigorous deductive reasoning, especially in subjects like geometry, due to a lack of exposure to tasks requiring formal proofs (Baines et al., 2022). These findings underline the importance of enhancing instructional strategies to promote abstract reasoning and formal deduction, helping students move beyond basic reasoning levels.

The second finding shows that students struggled to progress to higher levels of geometric reasoning, particularly Levels 3 (deduction) and 4 (rigor). Students at the higher education level often find it difficult to transition to abstract reasoning and formal deduction, which is necessary for solving more complex geometric problems (Tavares et al., 2021). While students may perform well on basic geometric tasks, they tend to struggle when faced with challenges requiring

formal proof, which is essential for advancing to higher Van Hiele levels. This finding reinforces the notion that instruction must go beyond basic geometric concepts to provide students with the tools to engage in rigorous logical reasoning.

Analysis of these findings indicates that students' low ability to achieve high levels of geometric reasoning is primarily due to a lack of opportunities to practice formal and deductive thinking. The learning process tends to focus on basic conceptual understanding and procedural application, without providing sufficient challenges to develop abstract thinking skills (Magtibay & Nueva España, 2023). As a result, students are only able to operate at a concrete and visual level of reasoning and struggle when faced with formal thinking demands such as constructing proofs or logical arguments.

This limitation also reflects the lack of systematic teaching strategies to guide students from intuitive to deductive reasoning. Without learning stages that provide gradual scaffolding, students struggle to grasp the formal mathematical structures underlying higher-level geometric reasoning (Nurwidyaningrum et al., 2022). Furthermore, the lack of integration of learning activities that encourage exploration, proof, and logical reflection prevents students from developing the rigorous thinking required at the highest levels of reasoning.

Geometry instruction needs to be redesigned to place greater emphasis on developing abstract and deductive thinking skills (Malik et al., 2024). This can be achieved through the provision of complex assignments, formal proof activities, and reflective discussions that require students to connect concepts, make generalizations, and construct logical arguments. This kind of approach will help students build a bridge from intuitive reasoning to rigorous reasoning which is the ultimate goal in learning geometry.

The findings of this study have significant implications for the teaching and learning of geometry at the university level. The results highlight the need for curriculum reforms aimed at enhancing students' geometric reasoning skills, particularly in the areas of formal deduction and mathematical rigor. Based on these findings, it is recommended that educators focus on providing students with more opportunities to engage in challenging geometric tasks that require higher-order reasoning. This could include tasks that emphasize formal proof construction, logical argumentation, and abstract reasoning. Additionally, assessment tools should be designed to evaluate students' progression across all Van Hiele levels, from visualization to rigor, to ensure that all aspects of geometric reasoning are adequately measured. By implementing these changes, educators can better support students in developing the critical thinking and problem-solving skills necessary for success in mathematics and related fields.

CONCLUSION

This study highlights the challenges that students face in progressing through the levels of geometric reasoning as defined by Van Hiele's theory, particularly in moving beyond basic visualization and analysis to more advanced levels such as

deduction and rigor. The findings indicate that many students remain at lower levels of reasoning due to limited exposure to tasks that require abstract thinking and formal deduction. The study emphasizes the need for curriculum reforms and instructional strategies that focus on developing students' ability to engage in higher-order reasoning, such as formal proof construction and logical argumentation. By addressing these gaps, educators can better support students in advancing to higher levels of geometric reasoning, ultimately enhancing their overall mathematical competence and problem-solving abilities.

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